

FINAL REPORT FOR NASA—AMES AGREEMENT No. NAG 2-777
("UNIVERSITY OF WASHINGTON—NASA COLLABORATIVE
STUDIES ON THE RADIATIVE EFFECTS OF CLOUDS")
PERIOD OF GRANT 2/1/92–1/31/96

REPORT

This agreement covered cooperative studies between the University of Washington's (UW) Cloud and Aerosol Research (CAR) Group and NASA scientists on a variety of topics concerned with aerosols, clouds and radiation. Under this agreement the CAR Group obtained airborne measurements with its Convair C-131A in several field projects, analyzed data from these projects, and published results. These studies are summarized below.

(a) FIRE-I (Southern California, 1987)

The FIRE-I project was concerned with marine stratus clouds off the southern California coast. Although the field project was in 1987, analysis of FIRE data continued under NAG 2-7777.

A paper in the *Journal of Geophysical Research* in 1993 (98, 2729–2739), co-authored by Michael King (NASA/Goddard) and UW scientists, described the first simultaneous measurements of the microstructure and radiative properties of clouds affected by ship effluents ("ship tracks").

(b) LEADDEX (Arctic, 1992)

This project provided measurements (from the cloud absorption radiometer aboard the C-131A) of the bi-directional reflectivity of various ice surfaces, as well as solar absorption measurements in ice clouds. These data are being analyzed by our NASA/Goddard colleagues.

(c) ASTEX/MAGE (Azores, 1992)

Detailed *in situ* cloud microphysical measurements from the C-131A were obtained on several flights simultaneously with MODIS simulator measurements aboard the ER-2. In several cases, the C-131A flew within the "diffusion domain" in the clouds, which permitted determination of the single-scattering albedo and other optical properties of the clouds.

A number of experiments were carried out in which both the water surface and cloud decks were mapped for bi-directional reflectivity using the cloud absorption radiometer aboard the C-131A.

Aircraft intercomparisons, primarily for radiation measurements, were conducted with the British Meteorological Office C-130 and the French Fokker-27.

The CAR Group has published several papers on this data. NASA/Goddard scientists are continuing to study the radiometer data, and to compare the *in situ* airborne data from the C-131A with the MODIS simulator.

(d) Kuwait Oil Fires (1991)

The C-131A with its UW crew, together with Michael King (NASA/Goddard), Francisco Valero (NASA/Ames) and Peter Pilewskie (NASA/Ames) spent six weeks in the Arabian Gulf region in 1991 as part of the US Interagency Airborne Study of the Kuwait Oil Fires. A special section of the *Journal of Geophysical Research* was devoted to papers describing these studies (see *J. Geophys. Res.* 97, 14481-14580, 1992).

(e) SCAR-A (US East Coast, 1993)

This field project with the C-131A was concerned with the radiative properties of anthropogenic aerosols on the US East Coast. It was carried out in collaboration with Yoram Kaufman (NASA/Goddard). Several flights of the C-131A occurred simultaneously with NASA's ER-2 in order to obtain simultaneous *in situ* and remote sensing measurements of aerosols. These studies led to a paper entitled "Measurements of Some Aerosol Properties Relevant to Radiative Forcing in the East Coast of the United States" by Hegg et al. (*J. Appl. Meteor.*, 34, 2306-2315, 1995).

Work continues with Yoram Kaufman in utilizing the SCAR-A data set for validating remote sensing measurements with MODIS.

(f) MAST (1994)

In 1994 the CAR Group participated in the Monterey Area Ship Tracks Experiment (MAST). Although the focus of this project was ship tracks, it also provided some simultaneous C-131A and ER-2 measurements on marine stratus clouds, which our NASA/Goddard colleagues (King, Tsay, Platnick) are studying.

(g) SCAR-C (Washington, 1994)

This field study, which was carried out in collaboration with Yoram Kaufman and Michael King of NASA/Goddard, was concerned with emissions from forest fires on the west coast. Some excellent *in situ* data on smoke plumes was obtained aboard the C-131A simultaneously with ER-2 (MODIS) overpasses.

(h) ARMCAS (Alaska, 1995)

During the field project, based out of Prudoe Bay, Alaska, the UW C-131 crew worked with the NASA ER-2 team (King and Tsay) to obtain simultaneous data sets on arctic clouds. Surface reflectivity measurements on various surfaces, and aerosol closure experiments over NASA sunphotometers (operated by Brent Holben and Tom Eck of NASA-Goddard) were also carried out.

(i) SCAR-B (Brazil, 1995)

SCAR-B was a large NASA-organized field project to study smoke from biomass burning in Brazil. In this project, the UW team worked closely with several NASA scientists (Kaufman, King, Tsay, Holben, etc.). The C-131 flew 29 research flights, several beneath the ER-2 and satellites, covering large areas of tropical and sub-tropical Brazil. Extensive measurements were obtained on the physical and chemical properties of the smokes from biomass burning in these regions. A report has been written and distributed that lists the data acquired aboard the C-131 in SCAR-B (Hobbs, 1996).

Analysis of SCAR-B data is expected to take several years.

(j) Data Archiving

Following quality assurance (QA) evaluations of the various data sets mentioned above, the C-131 data have been archived at the center officially designated for each project.

(k) Modeling Studies

In addition to the field studies described above, and associated analysis efforts, several modeling studies with Brian Toon (NASA/Ames) were carried out under NAG 2-777. These

studies involved graduate student Andrew Ackerman, who is now a NASA post-doc with Brian Toon.

**PUBLICATIONS DESCRIBING WORK SUPPORTED WHOLLY
OR IN PART BY NAG 2-777**

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